Syllabus for Physics 504, Fall 2020

Advanced Classical Mechanics

Itzhak Bars
SSC 216B, X-00047, bars@usc.edu

http://physics.usc.edu/~bars/

See Blackboard for assignments, posted documents, and useful links

Class times: Tu & Th 2:00-3:50 PM, Zoom link at Blackboard
Office hours: Tu & Th 5:00 – 6:00 PM, Zoom link at Blackboard

Grader: Ashton Lowenstein, alowenst@usc.edu

Pre-requisites

Classical Mechanics at undergraduate level.

Books

— *Classical Mechanics*, third edition, Addison-Wesley, 2002,
Authors: H. Goldstein, C. Poole and J. Safko.
— *Classical Dynamics: a Contemporary Approach*, Cambridge University Press, 1998,
Authors: J.V. José and E.J. Saletan.
— *Mechanics*, 3rd edition, Course in Theoretical Physics, vol.I, Pergamon Press, 1988,
Authors: L.D. Landau and E.M. Lifshitz.
— Material from other sources will also be used, and provided in the form
of posted class notes or internet links.

Lectures & participation

We will have 26 online classes. The topic of discussion for each class will be closely related to prior assigned reading (see schedule of classes), however the lecture may expand in additional and/or deeper directions, depending on students' questions and interest. The students are expected to have studied the **reading material before the lecture** and should be equipped to sharpen their understanding of the topic by asking questions and getting deeper insights from the teacher's presentation. To facilitate this process, a rough agenda for each class will be as follows:

- The class will start with a 15-minute presentation by a student chosen a priori from the roster in alphabetical order. The content of this presentation will include the student's overall rough understanding of the material (this need not be perfect). Furthermore, the student will consult with all participants sometime before class to compile a written list of all questions and make it part of the 15-minute presentation.
- This will be followed by a roughly one-hour lecture by the teacher that focuses on the most essential points in that day's topic and provides answers to questions raised by the students. There may not be sufficient time for the lecture to cover all the assigned reading matter, but the students are expected to digest all the reading and lecture content. If there are remaining questions, the students are responsible for bringing them up either during the office hour or during the current class or the following one

(preferable over office hour, so everyone benefits from the answer).

- This will be followed by a half-hour problem solving session in which the theory is applied to show how the formulas are interpreted in physical examples.

- The class will conclude with an overall brief summary.

Grading

- 30% - In class participation is expected in the form of asking questions and answering them during the teacher's lecture as well as periodically presenting a summary of assigned reading material and related questions as described above. The goal is to generate class discussions and greater interaction between students and teacher. 30% of the grade will be assigned on the basis of in-class active performance by the student.

- 30% - Homework problems will be assigned approximately once per week in Blackboard. Many sources with solutions to problems are available in the internet. Students can share ideas but are expected to write up their own work *clearly.* Copying solutions from each other, from the net or a solution manual will be considered plagiarism and will result in an automatic F grade for the course*. The homework assignments, which should be turned in by the Thursday of the following week, will be graded. The solutions will be posted in Blackboard.

  *See: Academic Integrity Overview , Trojan Integrity Guide , Guide for Graduate Students

- 40%- One of the following. This choice will be decided during class on Thursday, October 15. Either a final exam, on Tuesday, November 17, 2-4 p.m., Or an oral presentation and a related written assay (10 typed pages or more) on a topic of your interest connected to the material of this class (see course content below). This will be possible provided we can allocate a couple of full days during the exam period (Nov.17-24) for the whole class to listen to the half-hour oral presentations of all the students.

Course content

This course will emphasize the Lagrangian and Hamiltonian formulations of classical mechanics based on the action principle. Various standard topics, such as canonical transformations, constrained system, small oscillations, Kepler problem, Hamilton-Jacobi theory, scattering theory and others will be covered. Some newer topics of current interest, such as some aspects of cosmology, global symmetry, gauge symmetry will also be discussed. The overall discussion will be developed at first in the context of non-relativistic dynamics and later will include examples in relativistic dynamics and continuous systems, including classical field theory. Throughout the discussion, examples will be provided as applications in various branches of classical and modern physics.

The material that will be covered is listed below in broad outline. For an order of presentation see the attached schedule of lectures. A lot of the concepts are in some form in the book by Goldstein et.al. as well as the other recommended books. However, some of the topics are not well covered in these books. The material for more modern topics, such as cosmology, global symmetry, gauge symmetry and 2T-physics will be available as handouts or published papers.

§ Elementary principles of mechanics.
§ The action principle and the Lagrangian.
§ The Hamiltonian approach and phase space.
§ Examples in non-relativistic and relativistic dynamics.
§ Oscillations.
§ Central forces & Kepler problem.
§ Canonical transformations.
§ Global symmetries and conservation laws.
§ Constraints & gauge symmetries.
§ Cosmology as an example of a constrained system in general relativity.
§ Two-Time physics in classical particle dynamics.
This is a deeper space-time structure underlying of all 1T-physics.
It is also an example of gauge symmetry & related constrained systems.
§ New hidden symmetries and dualities predicted by 2T-physics (and missed in 1T-physics).
§ Hamilton-Jacobi theory. Action-angle variables and integrable systems.
§ Canonical perturbation theory.
§ Scattering theory.
§ Rigid bodies.
§ Continuous systems, field theory and string theory.
§ Chaos.

Time will likely not permit to cover all the topics (see tentative schedule below). In that case a selection will have to be made among the topics that are at the end of this list. It will all depend on how quickly the topics in the first half of the list can be absorbed by the students. It will also depend on the level of interest expressed by the participants. Therefore, anytime during this course, **make your preferences known** during the meetings or by writing an email to I. Bars about what you would like covered. In any case, students are advised to study on their own the topics that will not be covered in the lectures. In particular, those can be possible "final projects" to be presented by each student during the final period (Nov.17-24).

Student Ombudsman

All courses in the Department of Physics & Astronomy have an assigned Student Ombudsman to serve students as a confidential, neutral, informal, and independent resource when they wish to discuss issues concerning their course without directly confronting their instructor. The Student Ombudsman for this course is: Krzysztof Pilch, pilch@usc.edu, (213) 740-1145, SSC 202.

Additional Information

Advanced Mechanics Section 50604, **Session Dates** (session code **060**)

First day of classes: Monday, August 17, 2020
Last day to add: Friday, September 4, 2020
Last day to drop without a mark of "W" and receive a refund: Friday, September 4, 2020
Last day to withdraw without a "W" on transcript or change pass/no pass to letter grade: Friday, October 2, 2020
Last day to drop with a mark of "W": Friday, November 6, 2020
End of session: Tuesday, November 24, 2020

Tentative Schedule of Classes and Assignments

The following schedule is and will remain work in progress.

It will be modified as we go along to keep pace with the progress being made,

so it is essential that you review it weekly to make sure you do the correct weekly assignments.

Read the assigned material and solve the problems for the week. Students take turns (alphabetically) to provide a presentation as outlined in the syllabus. Turn in your solutions to the homework problems on the Thursday of the following week (see corresponding Blackboard link). Be prepared to present your solution of the problems online when asked to do so by sharing your screen and answer other relevant questions during class.

Week of 08/17/2020. Elementary principles of mechanics.
Read Chaps.1,2 in Goldstein
Solve problems in Goldstein ch.1, problems # 4, 9, 13, 14, 17, 22.
Week of 08/24/2020. The action principle, the Lagrangian and Hamiltonian.
Read Chaps 2,8.# in Goldstein.
Solve problems in Goldstein ch.2, # 2, 12, 14, 18, 21, 23, 25.
Week of 08/31/2020. Hamiltonian, Phase Space, Canonical transformations.
Read Chaps.#8,9 in Goldstein
Solve problems in Goldstein ch.8, # 2, 14, 16, 19, 23, 26, 27.
Week of 09/07/2020. Phase Space, Canonical transformations.
Read Chap.#9 in Goldstein
Solve problems in Goldstein ch.9, # 1,4,5,6,8,21,23.
Week of 09/14/2020. More on canonical transformations and Poisson Brackets.
Read Chaps.#9 in Goldstein
Solve problems assigned in class.
Week of 09/21/2020. Oscillations.
Read Chap.# 6 in Goldstein
See also the posted file about a string as an infinite number of points.
Solve problems in Goldstein ch.6, # 4,6,10,13,16.
Week of 09/28/2020. More on Oscillations and small perturbations
Read more of Chap.# 6 in Goldstein, and posted file about the 3-body problem.
Solve problems assigned in class
Week of 10/05/2020. Central forces & Kepler problem.
Read Ch.#3 in Goldstein
Solve problems in Goldstein Ch.3, # 11,13,14,18,19,21,27,31.
Week of 10/12/2020. More on Central forces.
Read more of Read Ch.#3 in Goldstein
Solve problems assigned in class.
Week of 10/19/2020. Central forces & Kepler problem, scattering.

Read more of Read Ch.#3 in Goldstein

Solve problems in Goldstein Ch.3, problems 11,13,14,18,19,21,27,31.

Week of 10/26/2020. Global Symmetry, Noether's Theorem and Conservation Laws

Read posted notes on symmetry.

Solve problems assigned in class.

Week of 11/02/2020. Examples of Symmetry, Properties of Symmetry Generators

Read more of posted notes on symmetry

Solve problems assigned in class.

Week of 11/09/2020. Hidden symmetries, H-atom, harmonic oscillator, Relativistic particle

Read notes on symmetry and on relativistic particle

Solve problems assigned in.

To the extent possible, I will try to fit in during the previous weeks at least the following topic on gauge symmetry and 2T-physics.

Gauge symmetry in particle dynamics – general formulation

Read posted notes on gauge symmetry in particle dynamics.

Solve problems assigned in class.

Examples of gauge symmetries, 2T-physics, cosmology

Read posted notes on 2T-physics

Solve the following problem sets:

Based on the 2T-physics document, do the following 4 problems: #1 and #2 in section-2, #1 in section-5, and #1 in section-6.

Solutions : For solutions see posted papers. The gauge choices or setup in the papers are slightly different but the solutions are equivalent (in problems 1,2,3 two gauge choices are made rather than 3 gauge choices, in problem 4 the second order formalism is used rather than the first order formalism).

FINAL: Tuesday Nov.17, 2-4PM
or decide on Oct.2 if final exam will be replaced by
Final project presentation, 2 days during week of Nov.17